Red Sea Studies

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LONG-TERM GOALS

My long term goal is to contribute to our understanding of the dynamics of the exchange flow through the Bab al Mandab and it's effect on the general circulation and stratification of the neighboring Red Sea and Gulf of Aden.

OBJECTIVES

I want to determine whether the exchange flow through the Bab al Mandab is hydraulically controlled. In the event that control exists, I would like to determine the locations of the control section(s) and hydraulic jumps, the vertical structure (first or second internal mode) of the wave whose propagation is arrested at the control section (s), and the extent to which these factors are influenced by the earth's rotation influences. Once the hydraulics of the exchange flow are determined, I would like to determine the extent to which the Red Sea and Gulf of Aden stratification are influenced by the Bab al Mandab geometry.

APPROACH

The approach has been to analyze direct velocity measurements made by Profs. Bill Johns (RSMAS) and Steve Murray (LSU) over the period June 1995-April 1996 at the Hanish sill and the Perim narrows of the Bab al Mandab. I have developed a three-layer model with arbitrary, cross-strait bottom topography which is used to calculate the speeds of the first and second long internal gravity waves, given the Murray/Johns data. Calculations are made using monthly mean velocities and densities.

Also, the effects of rotation on an idealized version of Red Sea outflow are studied using analytical and numerical calculations of geostrophic adjustment in a channel at various rotation rates. This work is being carried out in collaboration with Drs. Karl Helfrich (WHOI), Dr. Eric Chassignet (RSMAS), and Mr. Allen Kuo (Columbia U.)

Finally, the effects of the Bab al Mandab inflow on the Red Sea surface circulation is investigated (with Dr. Gidon Eshel, WHOI) using analytical and numerical models of that body.

WORK COMPLETED

Monthly mean, long-wave speeds for the first and second internal modes have been calculated. The corresponding Rossby Radii of deformation have been computed.

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Comparisons with the 3-layer hydraulic model of Dr. David Smeed (IOS, England) have been made. The numerical and analytical models referred to above have been constructed.

RESULTS

According to the propagation speed calculations the Bab al Mandab exchange flow is substantially subcritical during each month of the year. Only the strongest tides might temporarily push the flow over the threshold to supercriticality. The flow is therefore not hydraulically controlled, at least not in the same way that it is in other well-known straits such as Gibraltar. During the summer months, when the Bab al Mandab has intermediate depth inflow sandwiched between surface and bottom outflow, the flow is subcritical with respect to the second internal mode. During the winter, when only surface inflow and deep outflow exists, the flow is close to the critical speed at the narrowest section. Error bars are wide enough to prevent a definitive conclusion. In addition, the Rossby Radius of deformation for the second internal mode is the same order as the width of the Bab al Mandab central channel, making neglect of rotation for this mode problematic.

IMPACT/APPLICATIONS

The most immediate impact is that the Bab al Mandab exerts much less influence on the Red Sea than, say, the Strait of Gibraltar does on the Mediterranean. Some influence may occur during the winter months though the second internal mode, however the way in which this occurs must still be determined. The importance of rotation for the second internal mode must be determined. These considerations have importance for numerical models of the Red Sea (such as the Navy SWAFS model) which place open boundary conditions at or near the Bab al Mandab.

TRANSITIONS

My findings are being fed to Prof. Massamichi Inoue (LSU) who has developed a regional numerical model of the Bab al Mandab with much more realistic topography and stratification than can be handled in my analytical calculations. I have also contacted Drs. Amy Bower and Jim Price (WHOI) who, along with B. Johns, may propose a study of the Red Sea outflow. Instruments placed immediately downstream of the Hanish narrows would resolve much of the uncertainty concerning the existence and nature of a mode-2 control and a possible hydraulic jump.

RELATED PROJECTS

1) The numerical modeling effort of Prof. Inoue described above.
2) The Navy SWAFS model (see below reference to Horton, et. al.)

REFERENCES

Horton, C., M. Clifford, J. Schmitz, and B. Hester (1994) SWAFS: Shallow Water Analysis and Forecast System Overview and Status Report. Naval Oceanograhpic Office, Stennis Space Center.

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